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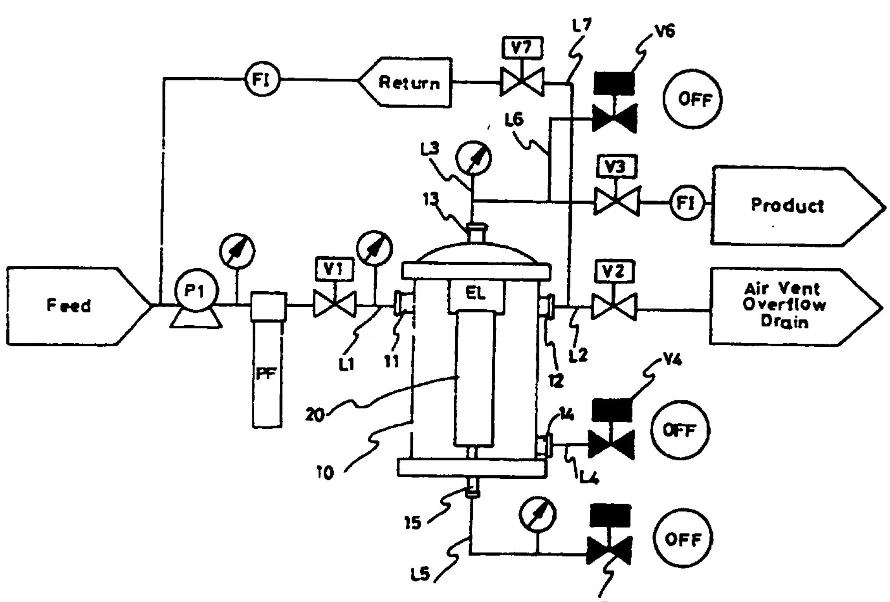
(54) Title: WATER TREATMENT SYSTEM USING HOLLOW FIBER MEMBRANE MODULE



(57) Abstract: A water treatment system using a hollow fiber membrane module is disclosed. The system comprises a housing provided with a main inlet port at the upper portion of its sidewall, an air and overflow outlet port at another upper portion of its sidewall, a main outlet port at the center of its top, a main drain port at the lower portion of its sidewall and an air inlet port at the center of its bottom; a hollow fiber membrane module is mounted in the interior of the housing and consists of a hollow fiber membrane element and an air diffusion tube; and a piping means.

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WATER TREATMENT SYSTEM USING HOLLOW FIBER MEMBRANE MODULE

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates, in general, to water treatment systems and, more particularly, to a water treatment system using a hollow fiber membrane module.

Description of the Prior Art

A water treatment is the act or process of making water more potable or useful, as by purifying, cleaning, softening, or deodorizing it. As well known to those skilled in the art, for a water treatment of a large amount of industrial water containing many solid suspensions, a complicated treatment process and a large-scale treatment system have been employed.

As a result, according to the conventional water treatment system, the water treatment with industrial scale is complicated, time-consuming and costly. Additionally, the treatment effect of the water treatment system is insufficient.

SUMMARY OF THE INVENTION

Accordingly, the present invention has been made keeping in mind the above problems occurring in the prior art, and an

object of the present invention is to provide a water treatment system, allowing the water treatment for industrial water to be easy, time-saving and cheap and improving the treatment effect of the water treatment system.

In order to accomplish the above object, the present invention provides a water treatment system using a hollow fiber membrane module, comprising: a housing provided with a main inlet port at the upper portion of its sidewall, an air and overflow outlet port at another upper portion of its sidewall, a main outlet port at the center of its top, a main drain port at the lower portion of its sidewall and an air inlet port at the center of its bottom; a hollow fiber membrane module mounted in the interior of the housing, the hollow fiber membrane module consisting of a hollow fiber membrane element and an air diffusion tube, the hollow fiber membrane element being communicated with the main outlet port, the air diffusion tube being communicated with the air inlet port and having a plurality of diffusion holes on its wall; and piping means consisting of a water supply line connecting a source of water with the main inlet port and having a first pump and a first valve, an air vent and overflow drain line being connected to the air and overflow outlet port at its one end and having a second valve, a treated water transfer line being connected to the main outlet port at its one end and having a third valve, a main drain line being connected to the main drain port at its one end and having a fourth valve,

an air supply line connecting a source of air with the air inlet port and having a fifth valve, a cleaning water supply line connecting a source of cleaning water with the treated water transfer line and having a second pump and sixth valve, and a return line connecting the air vent and overflow drain line with the water supply line and having a seventh valve.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and other advantages of the present invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

Fig. 1a is a schematic diagram showing a construction of a water treatment system using a hollow fiber membrane module according to the preferred embodiment of this invention;

Fig. 1b is a view showing the hollow fiber membrane module of the system;

Fig. 2 is a schematic diagram of the system in a normal mode;

Fig. 3 is a schematic diagram of the system in a back washing mode;

Fig. 4 is a schematic diagram of the system in a back washing mode and a vibration and stripping mode;

Fig. 5 is a schematic diagram of the system in a chemical

washing mode;

Fig. 6a is a microphotograph showing several hollow fibers;

Fig. 6b is a microphotograph showing a structure of a hollow fiber membrane element of an embodiment;

Fig. 6c is a microphotograph showing a structure of the interior portion of the hollow fiber membrane element;

Fig. 6d is a microphotograph showing a structure of the exterior portion of the hollow fiber membrane element;

Fig. 7 is a graph showing the permeability results of the system according to the size variation of the pore of the exterior portion of the hollow fiber membrane element;

Figs. 8 and 9 are graphs showing the permeability data measured according to the length variation of the fibers in the hollow fiber membrane element;

Fig. 10 is a graph showing the permeability results measured according to the operating time of a back washing and a vibration and stripping mode by minutes;

Fig. 11 is a graph showing the permeability results measured according to the operating time of a back washing mode and a vibration and stripping mode by hours;

Fig. 12 is a graph showing the water treatment efficiency results measured according to the operating time of the vibration and stripping mode by minutes;

Fig. 13 is graphs showing the water treatment efficiency results measured according to the operating time of the vibration

and stripping mode by minutes;

Fig. 14 is a graph showing the water treatment results measured according to the operating time by weeks; and

Fig. 15 is a graph showing the permeability data measured according to the number variation of fibers in the hollow fiber membrane element.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1a is a schematic diagram showing a construction of a water treatment system using a hollow fiber membrane module according to the preferred embodiment of this invention.

The water treatment system comprises a housing 10, a hollow fiber membrane module 20 and a piping means.

The housing 10 is provided with a main inlet port 11 at an upper portion of its sidewall, an air and overflow outlet port 12 at another upper portion of its sidewall, a main outlet port 13 at the center of its top, a main drain port 14 at the lower portion of its sidewall and an air inlet port 15 at the center of its bottom.

The hollow fiber membrane module 20 is vertically mounted in the interior of the housing 10 to range from the center of the top of the housing 10 to the center of the bottom of the housing 10. The hollow fiber membrane module 20 consists of a hollow fiber membrane element 21 and an air diffusion tube

22, the hollow fiber membrane element 21 being communicated with the main outlet port 13, the air diffusion tube 22 being communicated with the air inlet port 15.

A plurality of diffusion holes are formed on the wall of the air diffusion tube 22 so as to diffuse air toward the membrane element 21. The distribution density of the diffusion holes becomes dense along the downward direction. When the hollow fiber membrane module 20 is submerged under water, water pressure is applied to the air diffusion tube 22, so that it becomes difficult for air to get out of the lower portion of the air diffusion tube 22 through the holes of the lower portion. As a result, when distribution density of the holes is uniform across the entire tube 22, cleaning effect of the membrane element 21 by air diffusion is small at the lower portion of the tube 22. Incidentally, since the membrane element 21 must be vibrated like a string of a guitar and many pollutants adhere to the upper portion of the membrane element 21, holes must be formed at the upper and middle portions of the tube 22. In brief, relatively many holes are preferably formed at the lower portion of the tube 22.

With regard to the structure of the membrane element 21, since water is water-treated in the process of passing through the membrane element 21, the membrane element 21 is preferred to have a non-uniform structure in which relatively small pores are formed in its exterior portion and relatively big pores are formed in its interior portion, as shown in Fig. 6. When the pores in the exterior portion of the membrane element 21 are relatively big, the membrane element 21 is easily contaminated. The pore size of the exterior portion is preferred to be less than 0.1 μm, and more particular 0.01 μm for a vibration and stripping mode.

When the membrane element 21 has such a structure, the membrane element 21 not only is contaminated easily, but also is easily washed by a back washing.

The membrane element 21 is preferably designed to be inserted into the housing 10. When an O-ring is used, the mounting and removal of the membrane element 21 is easy.

The membrane element 21 may be covered with a tubular plastic net 23 for protection.

In this embodiment, the membrane element 21 preferably consists of four arcuate fiber bundle segments, each fiber bundle segment having 3,000 fibers, each fiber having 0.4 mm of an inside diameter and 0.6 mm of an outside diameter.

Since filtered water flows through the membrane element 21 and the passage of the water is the center hole of the membrane

element 21, a pressure loss occurs during its flowing. Therefore, the membrane element 21 has an optimum range of length so as to guarantee the water flow. The range of length of the membrane element 21 is 70-110 cm, preferably 80-90 cm. When the length of the membrane element 21 exceeds 110 cm, the filtering speed drops. As a result, it is very important to optimize the range of length of the membrane element 21.

The length of the membrane element 21 must be 0.5-5% longer than the length of the air diffusion tube 22 so as to vibrate the membrane element 21 with the air diffusion tube 22.

The piping means consists of seven pipelines. A water supply line L1 connects a source of water with the main inlet port 11 and has a first pump P1 and a first valve V1. An air vent and overflow drain line L2 is connected to the air and overflow outlet port 12 at its one end and has a second valve V2. A treated water transfer line L3 is connected to the main outlet port 13 at its one end and has a third valve V3. A main drain line L4 is connected to the main drain port at its one end and has a fourth valve V4. An air supply line L5 connects a source of air with the air inlet port 15 and has a fifth valve V5. A cleaning water supply line L6 connects a source of cleaning water with the treated water transfer line L3 and has a second pump P2 and sixth valve V6. A return line L7 connects the air vent and overflow drain line L2 with the water supply line L1 and has a seventh valve V7.

The operation of this embodiment is described in the following.

Referring to Fig. 2, a normal water treatment process is described. Water is supplied to the inside of the housing 10 through a water supply line L1 and the main inlet port 11. The supplied water is filtered by the membrane element 21 in the process of passing through the membrane element 21. The filtered water is discharged through the main outlet port 13 and the treated water transfer line L3. In this process, the fourth, fifth and sixth valves V4, V5 and V6 are closed.

When such a water treatment has been performed for a lengthy period of time, pollutants adhere to the exterior of the membrane element 21, thus reducing the permeating speed of the water. In such a case, the cleaning process for the membrane element 21 is required. In this system, the cleaning process can be performed by a back washing mode, a vibration and stripping mode and a chemical cleaning mode.

The cleaning process is described in more detail.

In the back washing mode shown in Fig. 3, the second and sixth valves V2 and V6 are opened and washing water is supplied to the interior of the housing 10 through the washing water supply line L6 and the main outlet port 13. The supplied washing water passes through the membrane element 21 and, subsequently, is discharged through the air and overflow outlet port 12. After a sufficient washing is performed, the washing water supply

is stopped and the fourth valve V4 is opened, so that the supplied washing water is discharged out of the housing 10. Subsequently, the normal water treatment process as shown in Fig. 2 is performed.

When the back washing mode is not sufficient to clean the membrane element 21, a back washing mode and a vibration and stripping mode may be performed at the same time. This process is illustrated in Fig. 4. In such process shown in the drawing, the second, fifth and sixth valves V2, V5 and V6 are opened, washing water is supplied to the interior of the housing 10 through the washing water supply line L6 and the main outlet port 13 and compressed air is supplied to the interior of the air diffusion tube 22 through an air supply line L5 and the air inlet port 15. According to the process, the back washing mode is not only performed, but the supplied compressed air diffuses through the holes of the air diffusion tube 22, the diffusing air vibrates the membrane element 21 and the pollutants adhering to the outside surface of the membrane element 21 are stripped.

Consequently, the permeating speed of the water is recovered and the efficiency of the water treatment is improved. After a sufficient cleaning is performed, the washing water and the compressed air supplies are stopped and the fourth valve V4 is opened, so that the supplied washing water is discharged out of the housing 10. Subsequently, the normal water treatment process as shown in Fig. 2 is performed.

When seriously polluted water is water-treated, the chemical cleaning mode is applied. This process is illustrated in Fig. 5. In such process shown in the drawing, the first and seventh valves V1 and V7 are opened and water containing a chemical cleaner is circulated through the water supply line L1 and the return line L7. After a sufficient cleaning is performed, the water supply containing a chemical cleaner is stopped and the fourth valve V4 is opened, so that the supplied water containing a chemical cleaner is discharged out of the housing 10.

EXAMPLE 1

In this example, the permeability of the system having the membrane element of 0.01 µm pore size and the permeability of the system having the membrane element of 0.1 µm a pore size were measured. The measured results are given in the graph of Fig. 7. As known in the graph, permeability is more stable in the case of 0.01 µm than in the case of 0.1 µm.

EXAMPLE 2

In this example, experiments were performed using the system shown in Fig. 1. The system had a hollow fiber membrane element consisting of four fiber bundle segments. In these experiments, the permeability according to the number variation of fibers in each bundle segment was measured. The measured results are graphed in Fig. 15. As shown in the graph, when the number of

fibers in each bundle segment was 3000, the permeability was maximized. When the number of fibers in each bundle segment was more than 3000, the permeability was lowered.

EXAMPLE 3

In this example, experiments were performed using the system shown in Fig. 1. In these experiments, the permeability according to the length variation of the hollow fiber membrane was measured. The measured results are graphed in Figs. 8 and 9. As shown in the graphs, when the length of the hollow fiber membrane element was 800 mm, the permeability was maximized.

EXAMPLE 4

While the back washing mode was conducted together the vibration and stripping mode in the system of Fig. 1, permeability variation of the membrane element was measured. The measured results are graphed in Fig. 10. The original water used in this example was the river water of Han River of Korea, the water having a turbidity of 4 NTU, 76 mg/L of SiO_2 and a temperature of 3°C. In these experiments, an operation pressure was 1.0 Kg/cm^2, while a pressure of the back washing was 1.5 Kg/cm^2. As known from this graph, when the vibration and stripping mode was conducted together with the back washing mode, the permeability was increased. In Fig. 11, the efficiency of the back washing mode is compared with the efficiency of the vibration and stripping

mode. In addition, the water treatment efficiency according to the time of the vibration and stripping mode was measured by minutes and the measured results are shown in Fig. 12. The water treatment efficiency according to the time of the vibration and stripping mode was measured by weeks and the measured results are shown in Fig. 13. The water treatment results according to the operating time by weeks were measured and the measured results are shown in Fig. 14.

As described above, a water treatment system of this invention allows the water treatment for industrial water to be easy, time-saving and cheap. Additionally, the water treatment system improves the water treatment effect.

Although the preferred embodiments of the present invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims.

WHAT IS CLAIMED IS:

1. A water treatment system using a hollow fiber membrane module, comprising:

a housing provided with a main inlet port at an upper portion of its sidewall, an air and overflow outlet port at another upper portion of its sidewall, a main outlet port at a center of its top, a main drain port at a lower portion of its sidewall and an air inlet port at a center of its bottom;

a hollow fiber membrane module mounted in an interior of the housing, the hollow fiber membrane module consisting of a hollow fiber membrane element and an air diffusion tube, the hollow fiber membrane element being communicated with the main outlet port, the air diffusion tube being communicated with the air inlet port and having a plurality of diffusion holes on its wall; and

piping means consisting of,

a water supply line connecting a source of water with the main inlet port and having a first pump and a first valve,

an air vent and overflow drain line being connected to the air and overflow outlet port at its one end and having a second valve,

a treated water transfer line being connected to the main outlet port at its one end and having a third valve,

a main drain line being connected to the main drain port

at its one end and having a fourth valve,

an air supply line connecting a source of air with the air inlet port and having a fifth valve,

a cleaning water supply line connecting a source of cleaning water with the treated water transfer line and having a second pump and sixth valve, and

a return line connecting the air vent and overflow drain line with the water supply line and having a seventh valve.

2. The system according to claim 1, wherein a distribution density of the diffusion holes becomes dense along a downward direction.

3. The system according to claim 1, wherein the membrane element has a non-uniform structure in which relatively small pores are formed in its exterior portion and relatively big pores are formed in its interior portion, the pore size of the exterior portion being less than 0.1 μm.

4. The system according to claim 1, wherein the membrane element consists of four fiber bundle segments, each fiber bundle segment having 3,000 fibers, each fiber having 0.4 mm of an inside diameter and 0.6 mm of an outside diameter.

5. The system according to claim 1, wherein a range of

length of the membrane element is 70-110 cm and a length of the membrane element is 0.5-5% longer than a length of said air diffusion tube.

6. The system according to claim 1, wherein the membrane element is covered with a tubular plastic net.

FIG. 1a

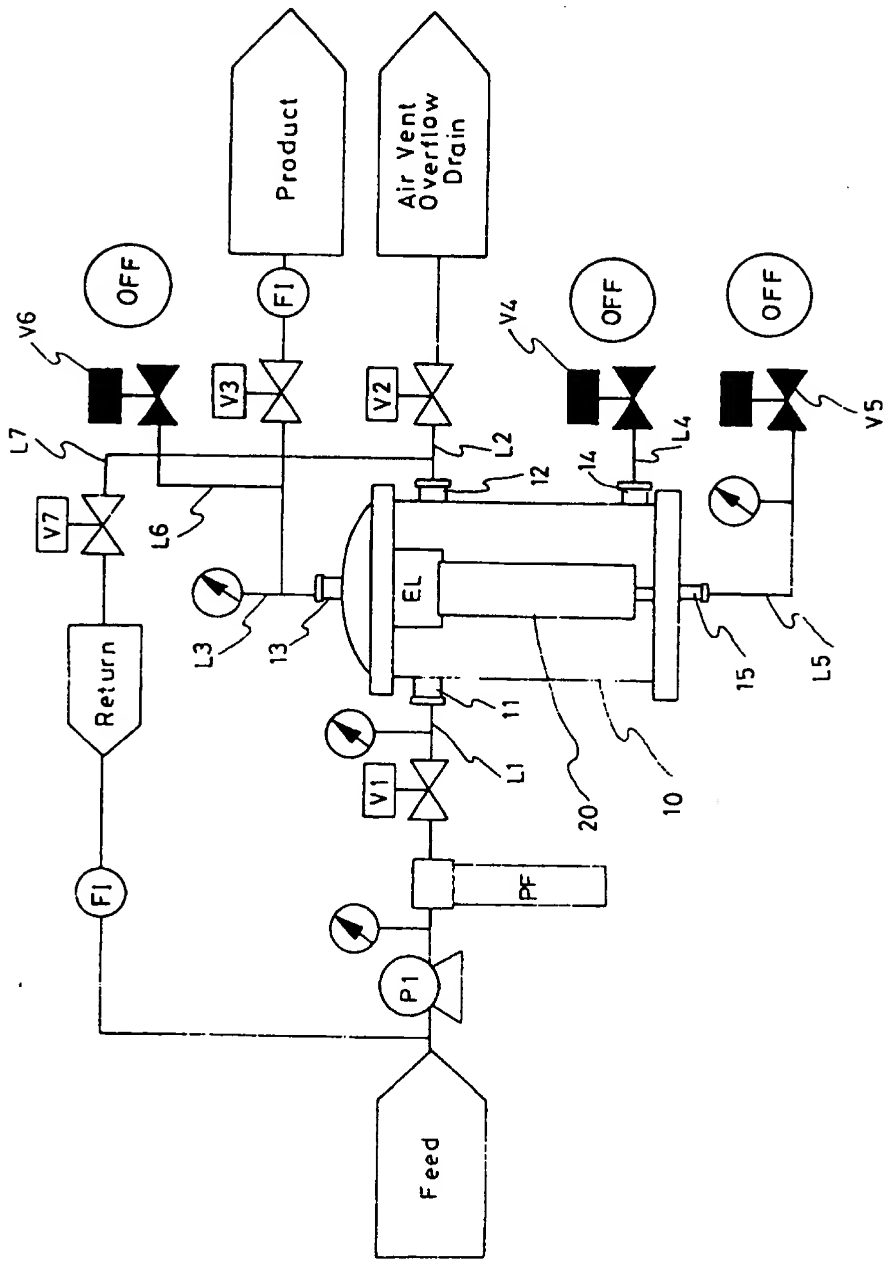
Product
Air Vent
Overflow
Drain
OFF
OFF
OFF
FI
FI
V1
V2
V3
V4
V5
V6
V7
L1
L2
L3
L4
L5
L6
L7
11
12
13
14
15
EL
20
10
Return
PF
P1
Feed

FIG. 1b

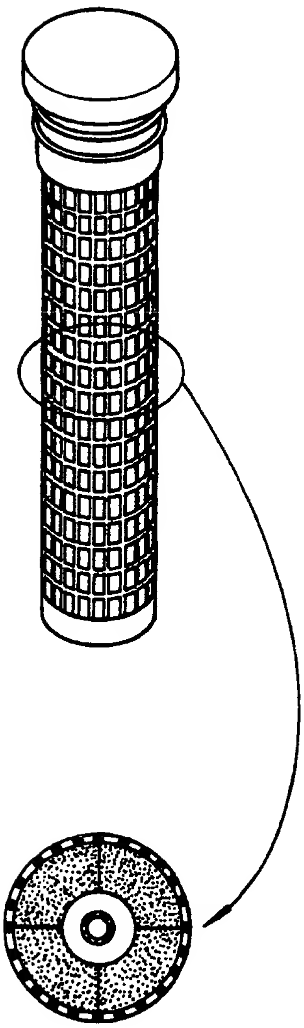

FIG. 2

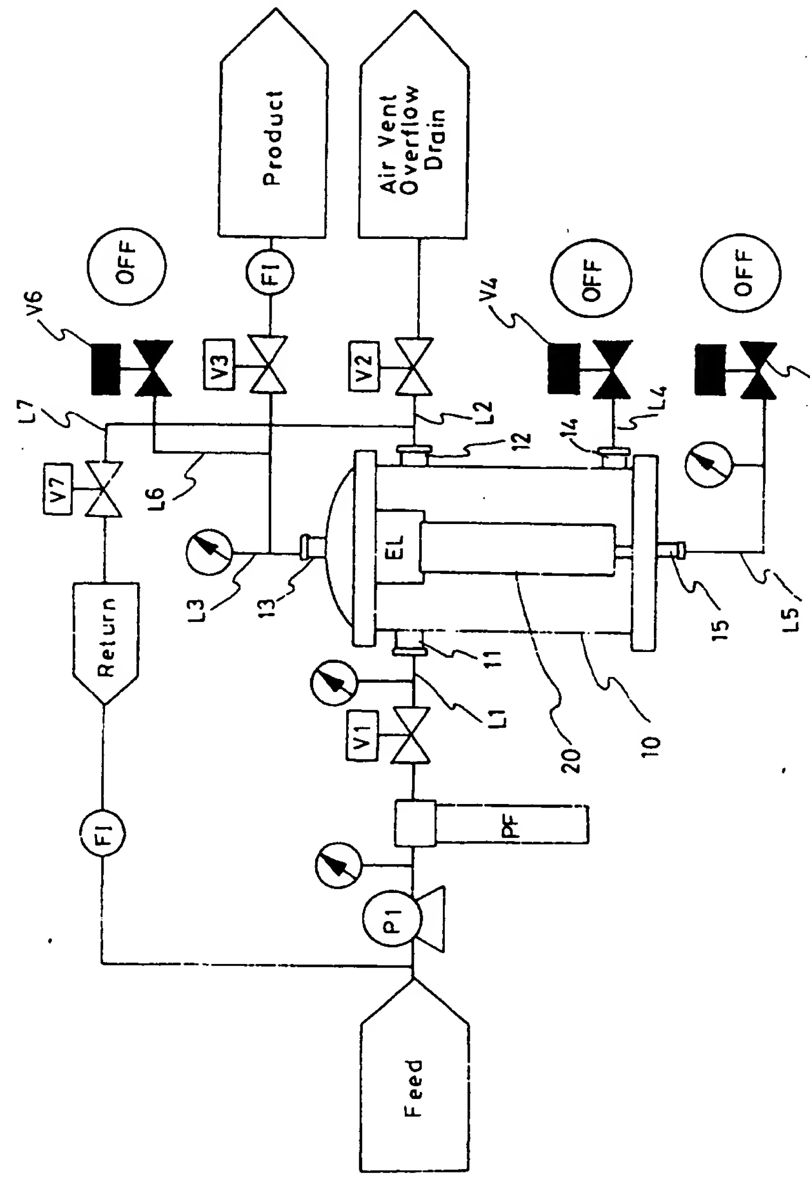
Product
Air Vent
Overflow
Drain
Feed
Return
OFF
OFF
OFF
FI
FI
V1
V2
V3
V4
V5
V6
V7
L1
L2
L3
L4
L5
L6
L7
EL
PF
P1
10
11
12
13
14
15
20

FIG. 3

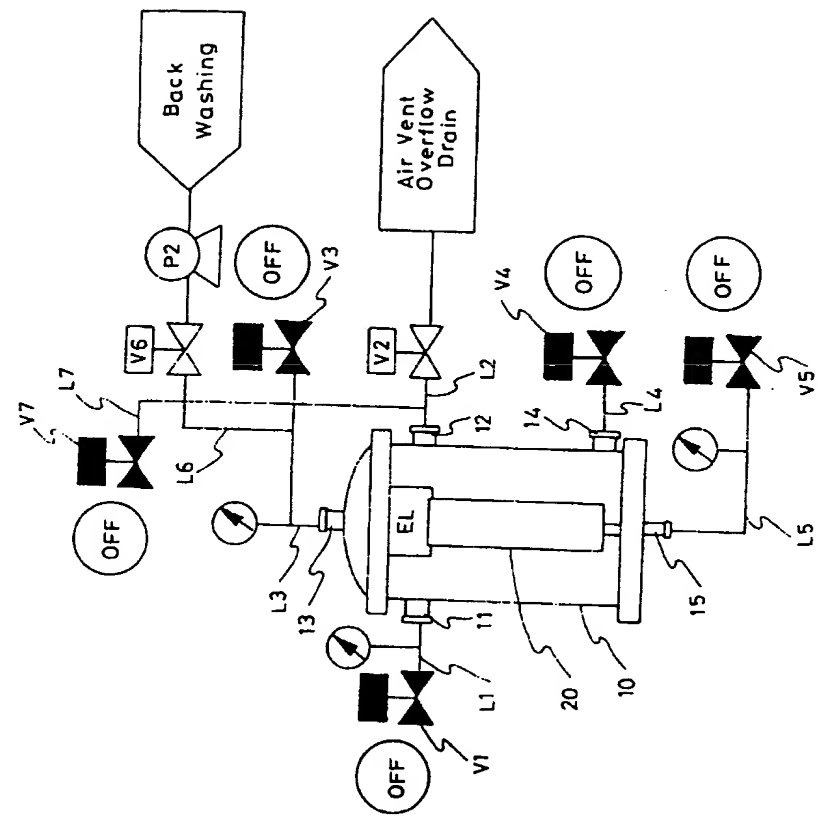
Back Washing
Air Vent Overflow Drain
P2
V6
V3
V2
V4
V5
V7
V1
OFF
L1
L2
L3
L4
L5
L6
L7
EL
10
11
12
13
14
15
20

FIG. 4

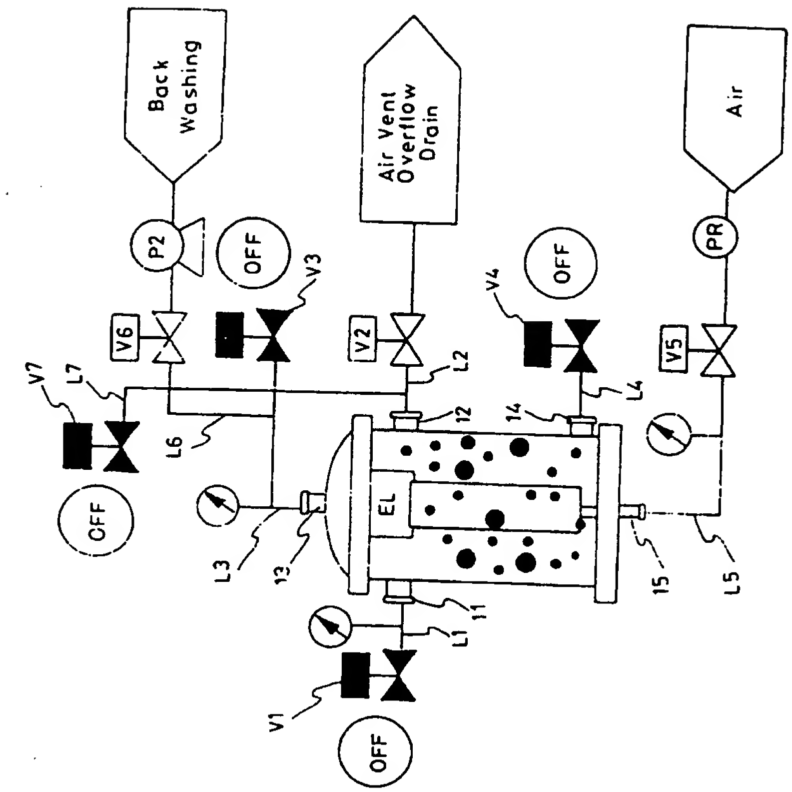
Back Washing
Air Vent Overflow Drain
Air
P2
PR
OFF
OFF
OFF
OFF
V1
V2
V3
V4
V5
V6
V7
L1
L2
L3
L4
L5
L6
L7
11
12
13
14
15
EL

FIG. 5

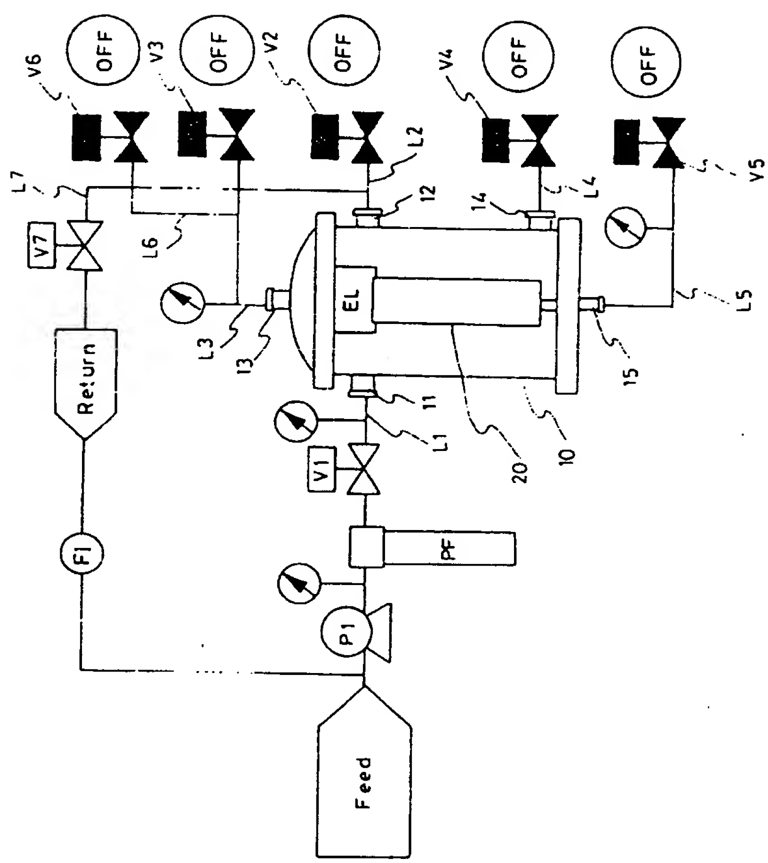
OFF
OFF
OFF
OFF
OFF
V6
V3
V2
V4
V5
L7
L6
L2
L4
L5
L3
L1
V7
V1
12
14
13
15
11
20
10
EL
Return
FI
PF
P1
Feed

FIG. 6a

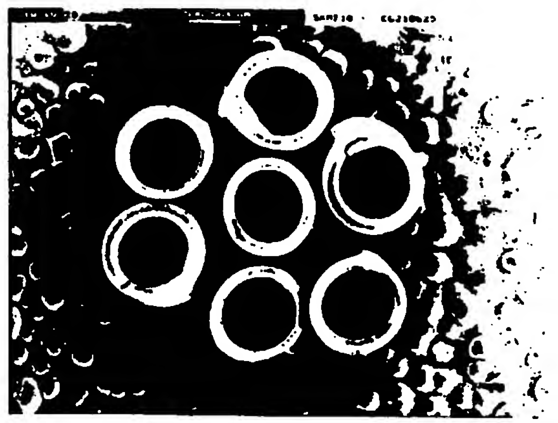

FIG. 6b

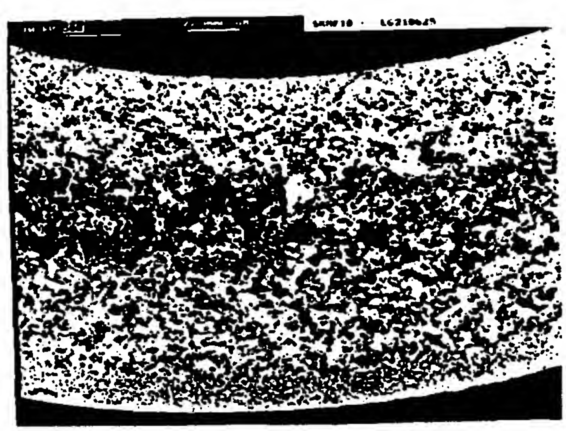

FIG. 6c

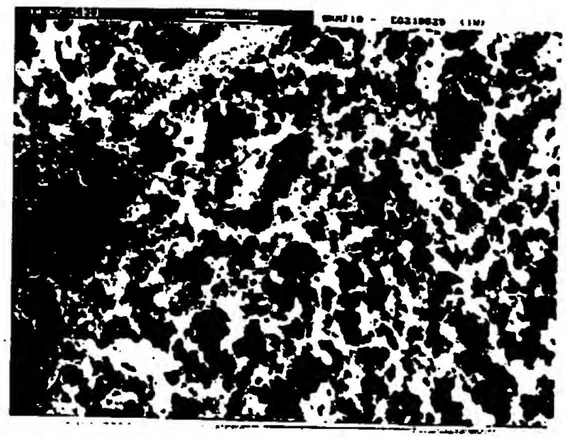

FIG. 6d

FIG. 7

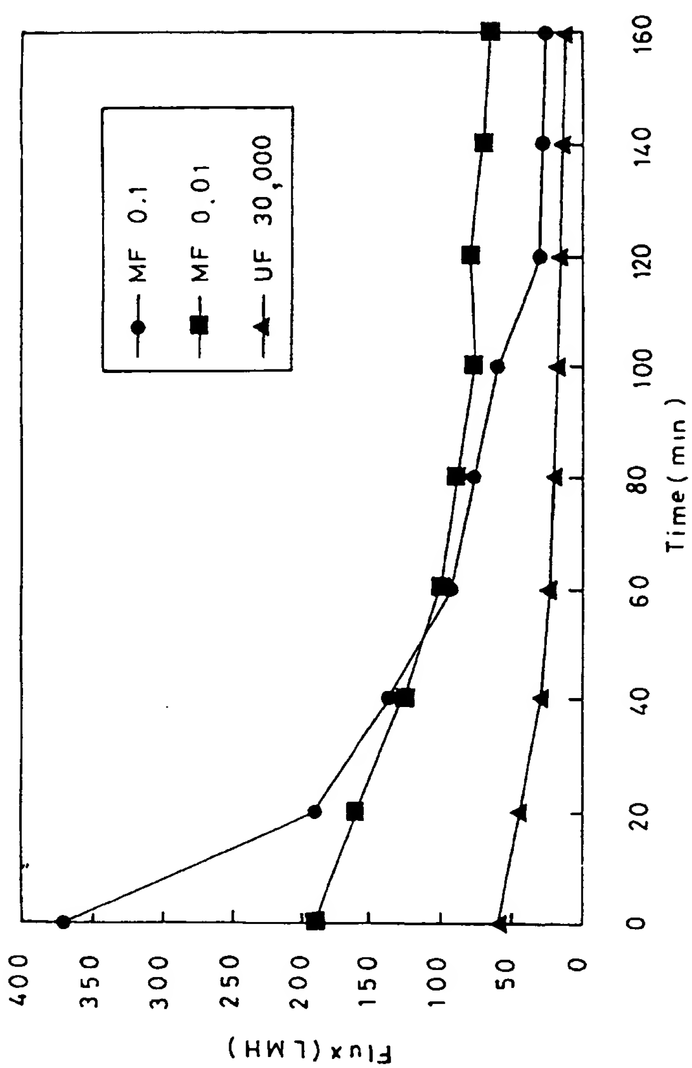
MF 0.1
MF 0.01
UF 30,000
Time (min)
Flux (L M H)
0
20
40
60
80
100
120
140
160
0
50
100
150
200
250
300
350
400

FIG. 8

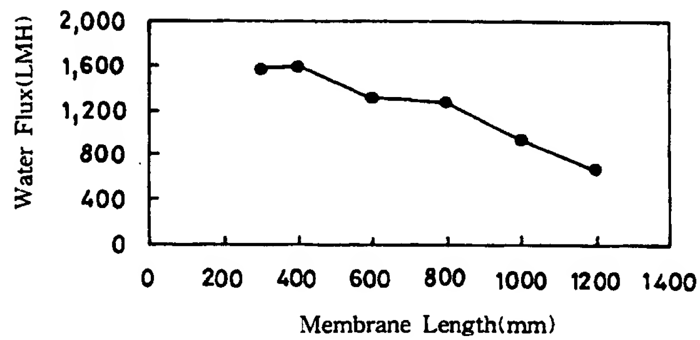
Water Flux(LMH)
2,000
1,600
1,200
800
400
0
0
200
400
600
800
1000
1200
1400
Membrane Length(mm)

FIG. 9

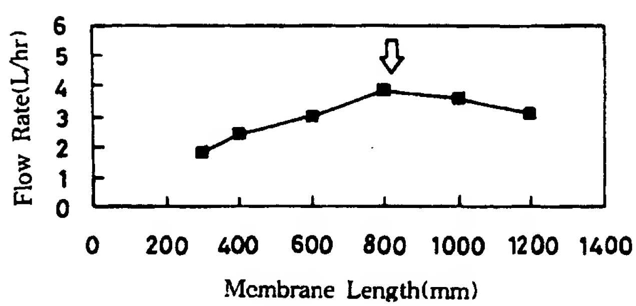
Flow Rate(L/hr)
6
5
4
3
2
1
0
0
200
400
600
800
1000
1200
1400
Membrane Length(mm)

FIG. 10

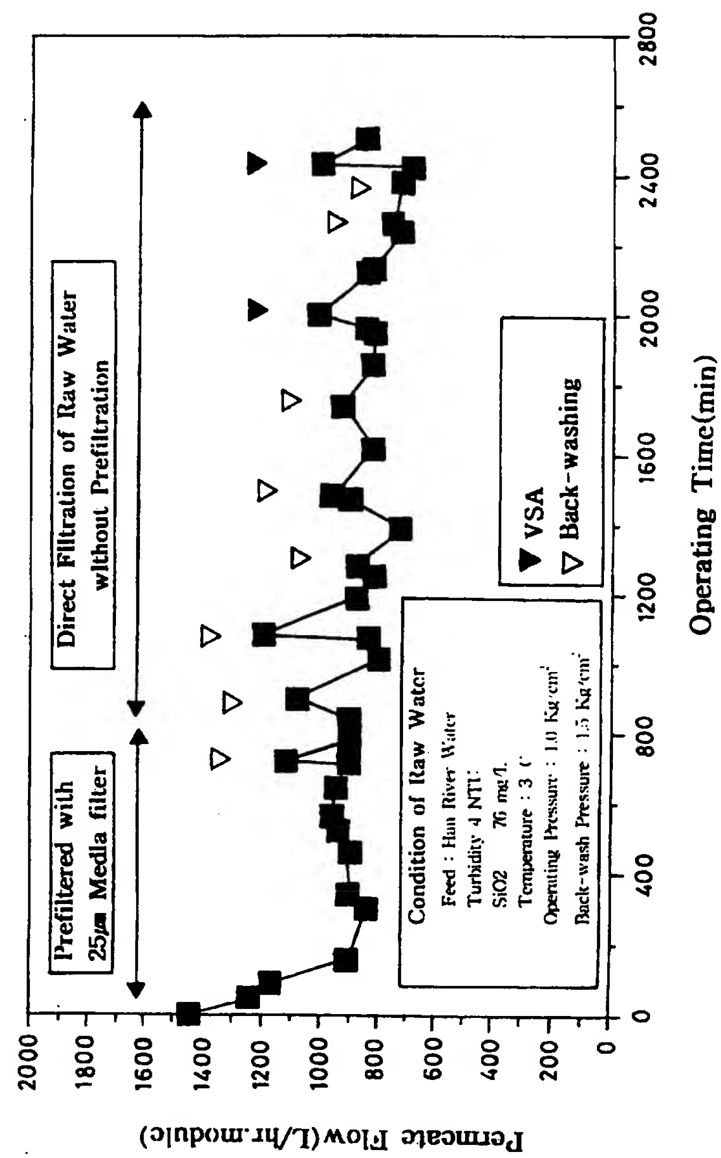
Prefiltered with 25μm Media filter
Direct Filtration of Raw Water without Prefiltration
Condition of Raw Water
VSA
Back-washing
Permeate Flow(L/hr.module)
Operating Time(min)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2400
2800

FIG. 11

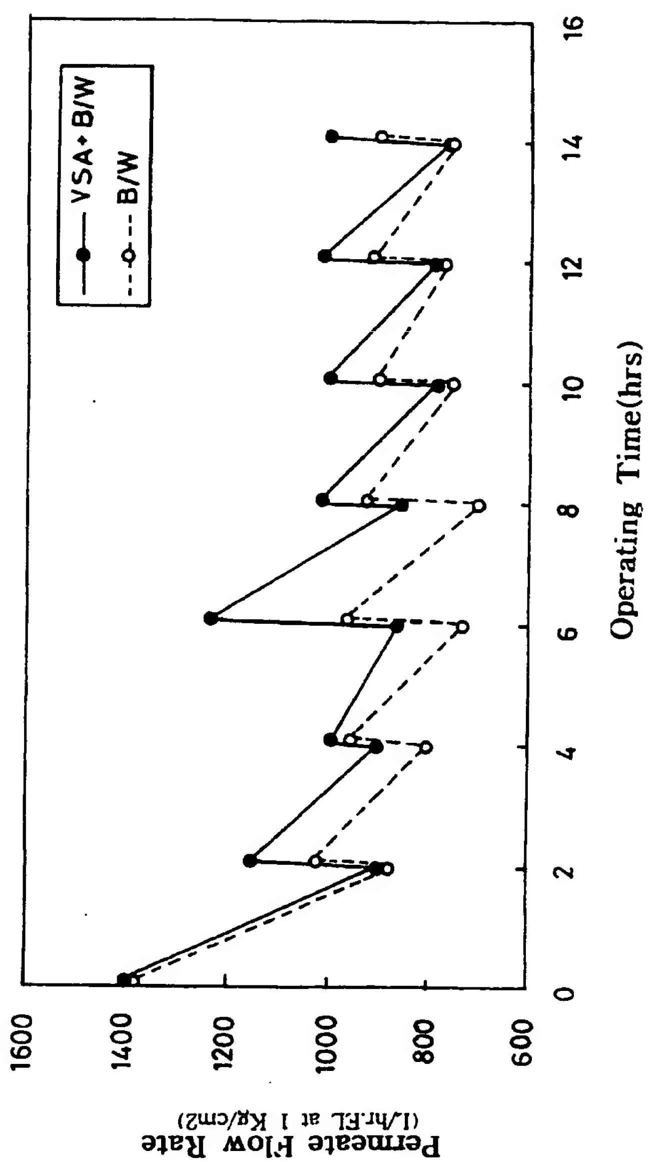
VSA+B/W
B/W
Operating Time(hrs)
Permeate Flow Rate
(L/hr.FL at 1 Kg/cm2)
0
2
4
6
8
10
12
14
16
600
800
1000
1200
1400
1600

FIG. 12

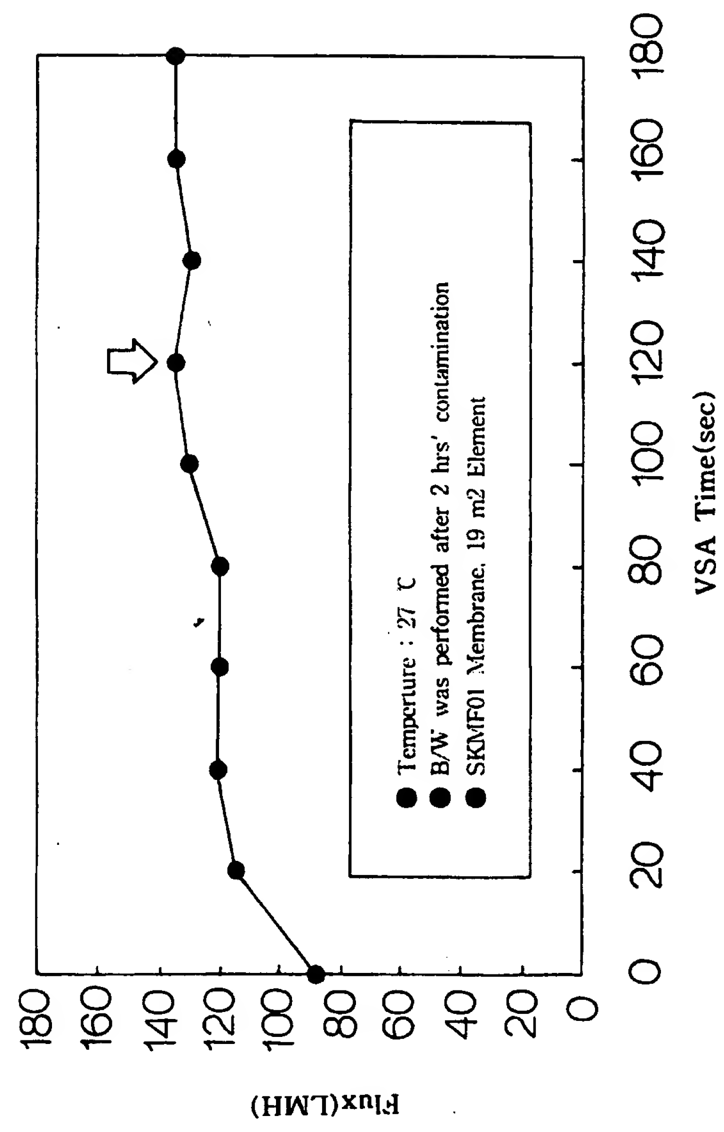
Temperture : 27 ℃
B/W was performed after 2 hrs' contamination
SKMF01 Membrane, 19 m2 Element
Flux(LMH)
0
20
40
60
80
100
120
140
160
180
VSA Time(sec)
0
20
40
60
80
100
120
140
160
180

FIG. 13

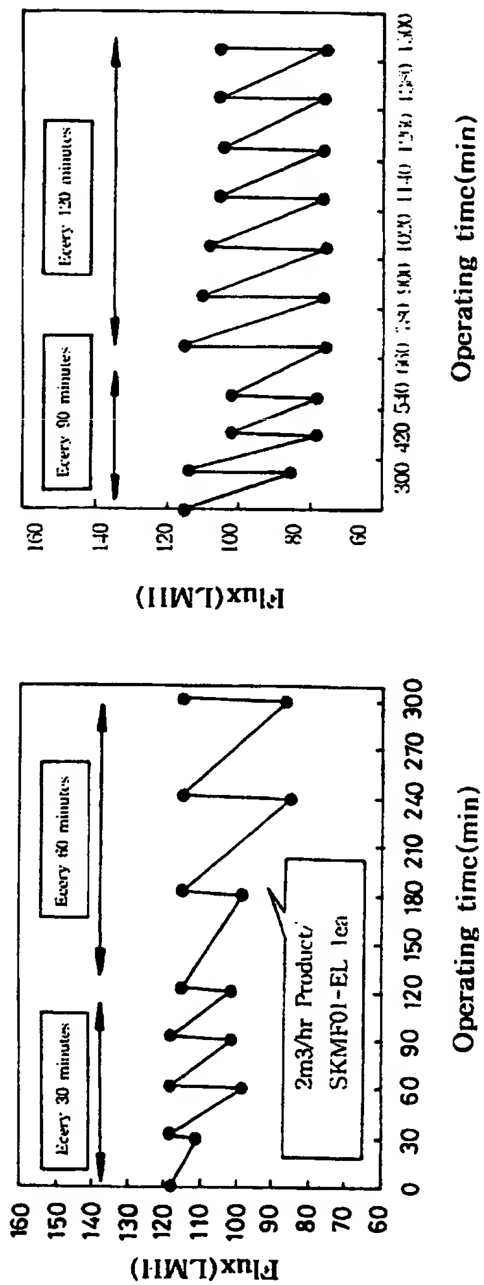
Every 30 minutes
Every 60 minutes
2m3/hr Product/
SKMF01-EL 1ea
Flux(LMH)
Operating time(min)
Every 90 minutes
Every 120 minutes
Flux(LMH)
Operating time(min)

FIG. 14

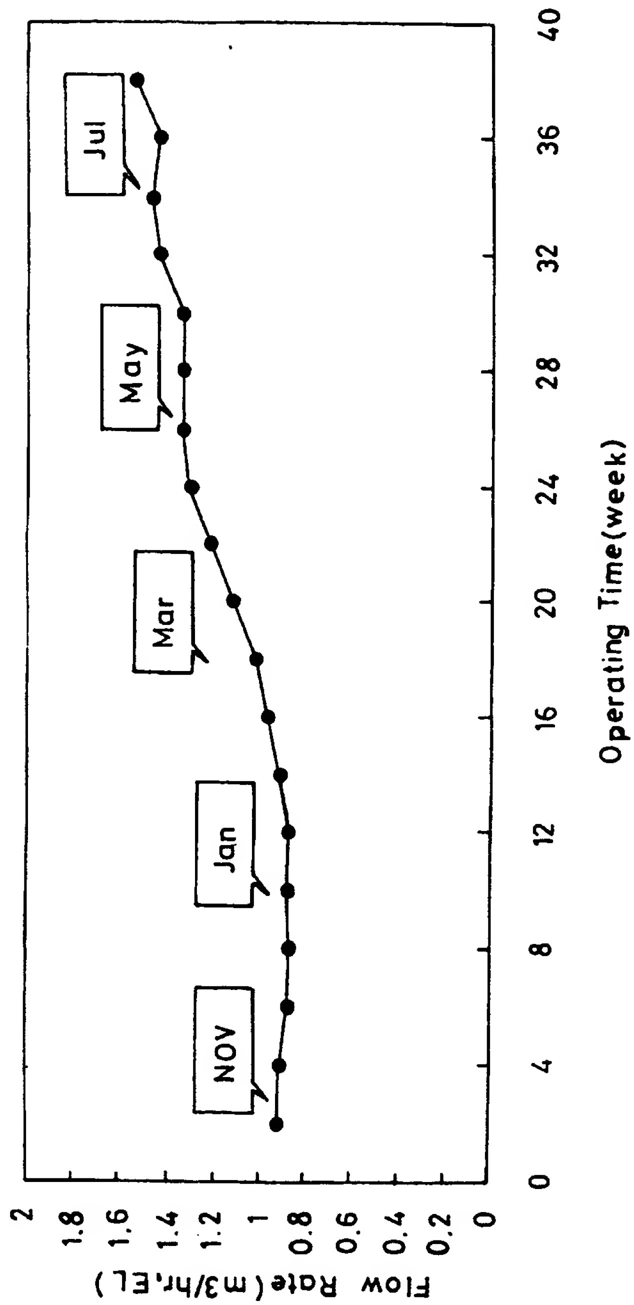
Flow Rate (m3/hr,EL)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Operating Time(week)
0
4
8
12
16
20
24
28
32
36
40
NOV
Jan
Mar
May
Jul

FIG. 15

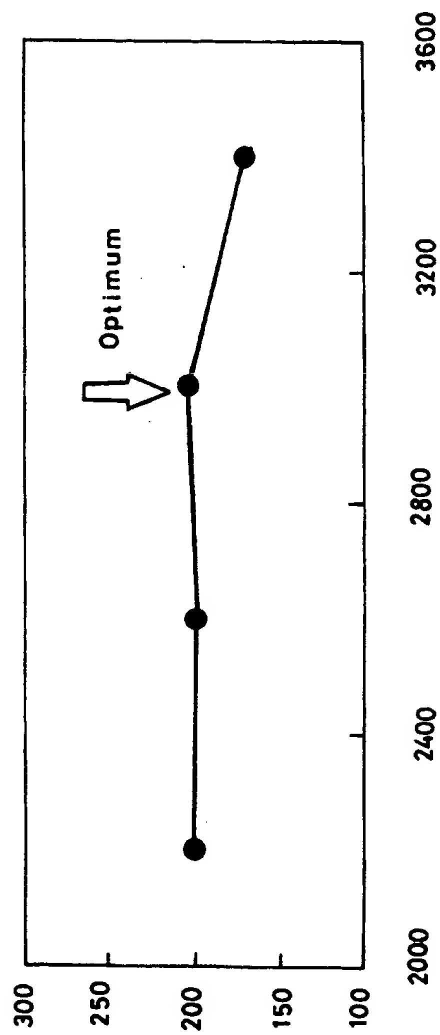

FIG. 16

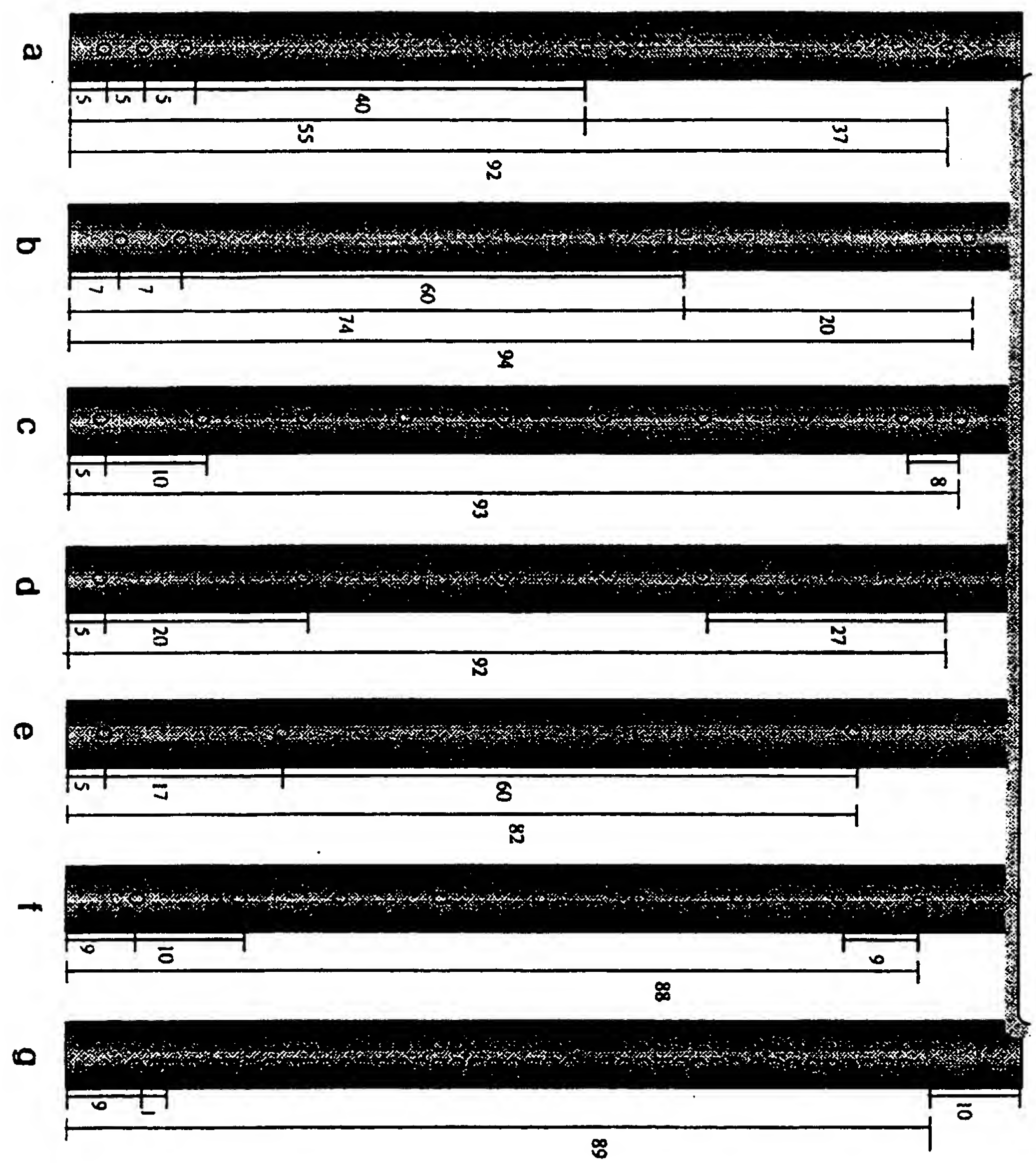
a
5
5
5
40
55
37
92
b
7
7
60
74
20
94
c
5
10
8
93
d
5
20
27
92
e
5
17
60
82
f
9
10
9
88
g
9
1
10
89

FIG. 17a

FIG. 17b

FIG. 17c

FIG. 17d

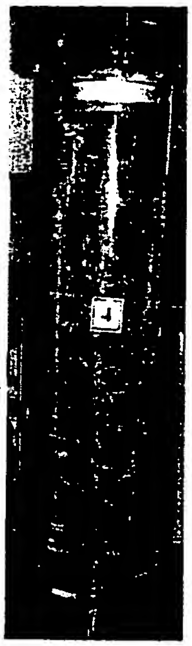

FIG. 17e

FIG. 17f

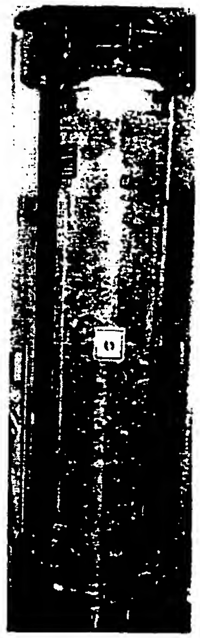

FIG. 17g

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR00/01060

A. CLASSIFICATION OF SUBJECT MATTER

IPC7 C02F 1/44

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimun documentation searched (classification system followed by classification symbols)
IPC7 C02F 1/44

Documentation searched other than minimun documentation to the extent that such documents are included in the fileds searched
Korean Patents and Applications for inventions since 1975
Korean Utility Models and Applications for Utility Models since 1975

Electronic data base consulted during the intertnational search (name of data base and, where practicable, search trerms used)
NPS, IPN, PAJ, CA

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 9-155345 A (HITACHI PLANT ENG & CONSTR CO., LTD.) 17 Jun 1997 see the whole document	1
P. A.	KR 2000-25870 A (SK CHEMICALS CO., LTD.) 6 May 2000 see the whole document	1, 3

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevence
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"Y" document of particular relevence; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 JANUARY 2001 (15.01.2001)	16 JANUARY 2001 (16.01.2001)

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR00/01060

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 9-155345 A	17 Jun 1997	None	
KR 2000-25870 A	6 May 2000	None	